1386953

PATENT SPECIFICATION

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(19)

(54) A PROCESS FOR MAKING MOULDED PLASTIC ARTICLES

(71) We, SHELL INTERNATIONALE RESEARCH MATTSCHAPPIJ B.V. formerly Shell Internationale Research Maatschappij N.V., a company organised under the laws of The Netherlands, of 30 Carel van Bylandtlaan, The Hague, The Netherlands, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

The present invention concerns a process for making thermoplastic moulded hollow articles, particularly suitable for use in the manufacture of travel luggage or the like and components for transport vehicles e.g. motor cars.

In recent years there has been an increase in the demand for luggage containers e.g. suitcases, travel cases and dual-purpose stationary and clothing cases and for accessory components for transport vehicles, e.g. facia panel trays and arm rests, and as a result traditional materials such as leather, wicker and straw have become too expensive, too scarce or too fragile for modern mass markets. The skilled labour and low production rates which are inherent in any manufacturing process using these materials have restricted their current outlets either to hand-made luxuries or specialised applications.

To supply the increasing demand for robust, lightweight mass-produced baggage many manufacturers now employ modern substitutes, e.g. fibreboard, leather-cloth, or synthetic fabrics. More recently thermoplastics such as ABS, have been employed, but the bulk of the market is supplied using the fibreboard shell.

Many qualities of fibreboard are now available. These consist of resin-impregnated vegetable fibre compressed to a uniform, dense sheet. The quality is determined by the resin type and content and the nature of the fibre, all of these contributing to the ease of moulding and resilience of the sheet. Feedstock for the luggage trade is generally decorated on either one or both sides, the external face generally with a varnished, leather-grain paper which imparts both appearance and a degree of water resistance. The finish of this outer veneer and also the decorative lining is as variable as is the fibreboard itself, and also contributes to the mouldability and appearance of the final luggage.

The forming process for fibreboard sheet is simple and well-established, and utilises cheap, readily-available machinery. Before forming, the sheet is cut into blanks, the shape of a blank being carefully contoured for each tool and luggage shell.

The moulding operation for fibreboard consists of the following steps.

(1) A blank is inserted between two heated rectangular clamping rings, and located by means of spring loaded centering lugs.

(2) The upper clamping ring is lowered to exert a positive clamping pressure on the trapped parts of the blank. Only the outer regions of the blank—those which are later subjected to extreme changes of shape—are trapped in the clamping rings. The centre of the blank remains as yet untouched.

(3) A short dwell time allows softening of the resin in the sheet in the trapped regions.

(4) Whilst maintaining the clamping pressure, both clamping rings are moved steadily downwards until the centre of the blank impinges on the domed upper surface of a heated male mould or pommel. The pommel is identical in shape to the final moulding.

(5) As the clamping rings continue their progress downwards, the tension caused by the pommel bowing the blank causes the fibreboard to begin slipping inwards through the clamping rings.

(6) As the slipping commences, the clamping rings are level with the top edge of the pommel. The dome is tightly wrapped by taut, warm fibreboard and as the rings progress downwards the warmed board is continually slipping out of the rings and is forced into intimate contact with the pommel by the

restricted clearance between the upper ring and pommel walls.

(7) When the blank has almost completely clipped out of the clamping rings, the downwards movement is stopped and a short dwell ensures. During this time the upper domed surface remains in tension and the walls of the forming remain trapped between the pommel wall and the inner surface of the upper ring.

(8) The rings are moved further downwards until the forming is clear of the upper clamping ring, yet still draped intimately over the pommel.

(9) The clamping rings move upwards and dislodge the forming from the pommel.

The critical factors in this process are the clamping pressures, temperatures and the clearances. The pressures are generally between 25 and 40 kg/cm^2, typically 32 kg/cm^2, and the slippage is promoted by the use of lubricants such as silicone polishes. Temperature of the rings and pommel are defined by the resin and varnish types, but generally fall within the range 60—100°C. The clearance between the upper ring and the pommel is significantly affected by these temperatures, and as this clearance plays a key role in the forming process the temperatures are as important as the tool design and set up to ensure that a suitable uniform gap is maintained.

As the surface area of the shell is smaller than that of the blank, some of the material is transferred into the vertical sides, and some is 'lost' into the corners. It is at the corners that most effort is concentrated during the process, and the excess fibreboard is gathered into wrinkles and then compressed into the ring/pommel gap. A good quality fibreboard can remould to some extent almost in the manner of a dough moulding compound, and little trace of the gathering will remain in the final corner. Less expensive fibreboard will merely bunch and then be flattened, and the designer relies on the leather-grain finish to disguise the remains of the wrinkles and puckers caused by the excess material.

The depth of draw with fibreboard is again controlled by feedstock quality, but even the best material will not allow more than two inches of vertical sidewall to be produced as corner faults are pronounced beyond this depth. In the subsequent fabrication of the cases, therefore, the depth of the luggage has to be built up by means of fibreboard strips stitched to the formings. A single suitcase therefore consists of two formed fibreboard shells, two strips of fibreboard to deepen case, two strips of aluminium or plastic extrusion to disguise the stitching joint, two edging strips in aluminium or plastics, one handle and fixing accessories, two lock and fixing accessories, four feet, two hinges and fixing accessories and two interior linings to disguise joints and fittings.

The assembly of a case is thus a relatively complex process and involves a great number of parts and stages. In addition to the production shortcomings, fibreboard is limited in the properties it can confer on a case. Even the best quality board is open to attack by a sharp knife, which renders the best locks ineffective, and rough handling by air or rail transport can puncture, scar or permanently dent the formings.

The quest for a superior article has involved many materials and processes. Injection moulding of an acrylonitrile/butadiene/styrene polymer, known commercially as ABS resin, has been attempted but tooling costs are severely limiting. Further, orientation of the ABS sheets induces brittleness and is difficult to overcome in such long flow path moulds. Weight limitations control the thickness. Reinforcement by ribbing is aesthetically objectionable on the interior, and causes sink-marks on the exterior which the leather-grain finish would not completely mask. Injection moulding has therefore been largely restricted to small compartmented luggage as large injection moulded shells have proved to be too expensive.

Vacuum forming offers an apparently simple method of luggage shell forming. The drawback of this process is that the corners thin during forming and thus the most vulnerable part of the case is the weakest, being both thinner and more open to impact failure due to the mode of forming e.g. internal stresses or slow cooling effects on crystallinity. By contrast, solid phase forming techniques have the effect of toughening the polyolefins and a forming produced by this route possesses the advantage of work hardening especially in the corners where the maximum effort is concentrated.

One aspect of the present invention is directed to thermoplastics moulded hollow articles especially articles suitable for use in baggage or luggage containers, and satisfies a need for a tough light-weight alternative to fibreboard.

The present invention therefore concerns a process for making a moulded hollow article which comprises heating a sheet of thermoplastics polymer to a temperature of between X°C and (X−35)°C where X is the crystalline melting point of crystalline polymers, or the "Vicat" softening point of amorphous polymers, clamping the sheet at its periphery by means of heated clamping rings and pressure slip-forming the sheet around a mould so that the thickness of the article is substantially the same as that of the polymer sheet.

The preferred polymer for use in the process of the invention is an olefin polymer e.g. polyethylene, or polypropylene homo- or

co-polymer, although copolymers with e.g. butene - 1 are suitable. Also suitable for certain uses are polymers or co-polymers of other materials e.g. PVC or ABS resins particularly for luggage cases and car components.

The process according to the invention utilises a preformed feedstock rather than the granules and powders employed in melt moulding. Suitably contoured polymer blanks are cut from sheet of the thickness required for the finished part. All the trimmings are recycled through the sheet extruder. During slip-forming plastic flow occurs in the solid state to maintain the sheet thickness.

In solid phase slip-forming of certain shaped articles a lower projection of polymer or "flash" may be formed at the corners. To eliminate this "flash", the blank is designed such that it is material-deficient in the corner regions. Flow in the solid state then produces a full corner by "flowing in" excess material from other parts of the blank during the forming process.

The process solid phase slip-forming will be further described in relation to polypropylene sheet, although other polymer sheet may be used, the temperatures then being somewhat different depending upon the crystalline melting point or softening point of the polymer.

1. The polypropylene blank is heated to within a few degrees of the crystalline melting point, i.e. in the range 135°C to 170°C, typically 153—157°C. Heating may be performed by either radiant heaters or using an oven.

2. The blank is inserted between clamping rings also heated to around 155°C, and periferally clamped.

3. A clamping pressure of 14 to 24 Kg/cm^2 is applied and the rings immediately moved downwards. The speed of movement of the rings is critical and closing rates of up to 1.8 m (60 inches) per minute have been successful.

4. As the sheet moves down contact with domed male mould results and the sheet tightens as the dome shape is imparted. When the blank between the clamping rings is level with the mould edge, slipping of the sheet out of the clamping rings results.

5. As the sheet leaves the clamping ring it travels up and around the radiused inner edge of the upper ring. It is then forced through a restricted gap being the space between the ring and the mould. This cold working permanently sets the sheet into the new shape, yet local thinning is avoided and all finished areas have equivalent thickness.

6. The downward movement and forming continues until all the sheet has slipped out of the clamping rings.

7. A short dwell ensues, then the moulding is ejected by upward movement of the clamping rings which carry the forming ahead due to slight spring back off the mould.

The process is sensitive to temperature, pressure and equipment design. For example, excessive blank or clamping ring temperature will, together with the heat generated during the working cause melting to occur giving a weak, mis-shaped part and clamping pressures in excess of 24 kg/cm^2 introduce a tendency to form ductile drawn regions, especially where the ring-pommel gap is marginally under-sized. The radius of curvature on the clamping ring edge is also a further factor in the process. Temperature control of the male mould is a convenient way of controlling the ring to mould clearance by virtue of the thermal expansion which occurs. Mould temperatures within the range 20°—100°C have so far been found suitable, the main criterion apart from the gap width being the ability of the pommel to act as a cooling and setting device to the hot sheet as it leaves the forming area.

The simplest form of polymer feedstock is single coloured polyolefin sheet with a gloss finish on both sides. The material is suitable for many markets, but where speciality items are required several variations in the feedstock quality or finish could be introduced. The colour may be varied by pigmentation and the use of laminated feedstock allows two tone mouldings to be produced. One or both surfaces may be decorated e.g. with embossing, to simulate natural or synthetic finishes. Embossing will be retained throughout the slip forming process although some variation occurs in the regions of cold flow.

In addition to laminated sheet, other materials may be used to modify one or both the surfaces of the polymer. These include film, cloth and flock, which may be introduced onto the surface of the sheet either during extrusion or as a subsequent process. The preferred form of cloth, film or flock would be that produced from a polyolefin similar to the sheet itself. The regrind produced from the trimmings may be used as a raw material for the extrusion of new sheet without the removal of the contaminating laminate. The use of thermoplastics other than the type employed in the sheet may suitably be used if a small proportion of the second polymer can be accommodated in the re-extrusion process. It is preferred for certain application however, to match the laminating material to the feedstock material so that the composite feedstock has uniform processing characteristics with respect to temperature and pressure. The ability of cloth, film and flock laminated feedstocks to form in the SPSF process will depend on their strength of adhesion to the sheet, and on their individual softening points.

Luggage shells have been produced from polypropylene blanks which exhibit a deeper draw than is possible with most qualities of

fibreboard, and depths of drawing in excess of 100 mm (4″) are possible. Using shells of this depth, a suitcase would then consist of two polyolefin shells, two hinges and fixing accessories, one handle, two locks and fixing accessories, two edging strips of aluminium and four feet.

The saving of six components over a fibreboard case allows a substantial saving in assembly time, production time for the deepening strips, and renders the masking extrusion unnecessary. The interior finish of the polyolefin can be made attractive using linings.

The solid phase slip-forming process is further described in detail. The shaped polymer blanks cut from the sheet are uniformly heated to a temperature suitable for the SPSF of that material, i.e. below the crystalline melting point of crystalline materials (for polypropylene 135°—170°C), or below the softening point of amorphous materials (for ABS 55°C—90°C) heating is accomplished using either hot air oven or radiant techniques.

Suitably, the heating stage should not control the speed of the forming cycle and a steady flow of heated blanks must be available at a predetermined rate. This may be achieved by use of a hot air tunnel of suitable length and traversing speed, or the use of one or more radiant heating stations. The tendency to overheat the surface whilst the centre of the sheet remains cool will limit the use of radiant heating to feedstock up to 2 mm thick. Minor temperature variations across the sheet may be avoided by a short dwell in the heated clamp rings, but this should be minimised for optimum cycle time.

The heated blank is accurately positioned on top of the lower clamping ring. This operation is facilitated by spring loaded lugs which compress into recesses as the clamping rings close. The transfer operation must be performed rapidly to reduce heat losses from the sheet and yet accurately to prevent eccentricity in the mouldings.

When the blank is clamped between the upper and lower rings and is at a suitable temperature, downward movement of the rings commences. The centre of the blank impinges on the domed centre of the mould and the sheet is draped and tautened over the surface. As the tension in the sheet increases, it eventually begins to pull the blank from between clamping rings. When the clamping rings reach the vertical sides of the mould the slipping blank suffers a 90° change in direction as it leaves the rings and is spread onto the male mould. The downward movement continues until the last of blank leaves the rings, but is still held against the mould walls by the inner surface of the upper ring.

After a short dwell to aid dimensional stability of the moulding the clamping rings are further moved downwards. When the rings clear the forming their movement is reversed and the moulding is stripped from the mould.

In its simplest form (Figure 1) the process produces hollow articles with vertical sides and a domed top. The shape of the article may vary i.e. circular, rectangular or have a combination of straight and curved edges. These formings may be produced from polymer or co-polymer sheet feedstock by a process in which the sheet is held at a temperature of between the crystalline melting point and 35°C below the crystalline melting point and is clamped by heated clamping rings at its periphery, and slip formed around a mould.

More complex forms of solid phase slip forming are required to produce more intricately shaped components. These may be attained by either a refinement of slip forming alone or by combining this technique with other solid phase forming techniques. Examples of these variations are shown in Figures 2—5. The first variation is produced by the use of a split clamping frame to produce stepped mouldings shown in Figure 2. Here the clamping frames consist of concentric independently driven frames, the lower ones being suitably contoured where they act as part of the male mould. The downward movement of the rings is initiated, but once the inner rings are arrested by contact with the mould, only the outer rings continue the downward movement.

Figure 3 shows the combination of solid phase slip forming and a rubber pad forging technique. The upper part of the mould has been replaced by a thick rubber block and, as the sliip forming operation commences, an independently driven forging tool is activated which compresses its contours into the rubber pad through the feedstock. The feedstock retains this shape on ejection.

The forging may be taken a step further as in Figure 4 where matched tooling is used to produce a complex shape on the crown of the slip formed moulding. Both these forging techniques are limited in the depth of draw which is obtainable without excessive thinning in the areas of maximum draw. This is in contrast to the even wall thickness obtained from the slip formed regions around the periphery.

Slip forming may suitably be combined with solid phase pressure forming as shown in Figures 5(1) and 5(2). This combination allows both convex and concave modifications to the basic slip formed moulding and requires an air-tight seal between the male mould and an independently activated pressure forming device. The female, secondary mould for the pressure forming may be cut into the male slip forming mould as in 5(1) or introduced as an independent mould situated vertically above the male slip forming

mould 5(2). In the first instance the forming air is introduced from a plunger situated above the sheet whereas in the second instance the plunger for the pressure forming is situated within the male slip forming mould. The pressure formed areas of the final moulding are thinner in cross-section than the original feedstock thickness or the slip formed area of the moulding.

These extentions to the SPSF process may involve modification or additions to basic machinery used for the simple SPSF process. The modifications, which are achieved by combination with another solid phase technique, have little effect on the slip forming process for shaping periphery. When the clamping frames have exerted counter pressure and the sheet has made contact with the male mould surface, the secondary forming operation functions as an independent process, whilst the remainder of the slip forming operation continues.

When slip forming and a secondary process are carried out in neighbouring areas of the feedstock, the two processes may interfere, causing distortion and thinning. In these instances the commencement of either the slip forming or the secondary process must be delayed sufficiently to allow the completion of the other process in the interfering area. The order in which the processes are used will be governed by the optimum forming temperature of each, as the feedstock is cooler for the second phase.

The efficiency of the process of slip-forming as previously described, depends upon a number of conditions being optional. These conditions are as follows:—

(a) Blank Temperature

The temperature of the material during forming is a crtical factor in the process. It is controlled by (i) the heating stage which raises the temperature from ambient (ii) the efficiency of the transfer from the heating zone to the clamping rings and (iii) the temperature of the clamping rings.

Too high a temperature leads to yielding and necking as the slipping force is applied, while too low a temperature leads to inadequate forming and poor definition.

(b) Clamping ring design

The clamping rings should preferably be uniformly heated to the correct forming temperature, thus electrical heaters around the rings are preferably continuous strip heaters controllable to within 5°C. Insulation of the outer surface of the rings assists temperature control.

Clamping surface area of the rings must be sufficient to accommodate all the sheet which is to undergo a severe change of shape. The internal dimensions of the rings are controlled by the size of the mould over which they are to pass. The clearance of the rings around the mould is controlled by the sheet thickness, and must be uniform to promote even distribution of material and work. Too wide a gap gives poor definition through lack of working, too tight a fit leads to necking and scuffing. Gap variability leads to a combination of these effects.

(c) Mould design

The mould is domed and preferably has parallel vertical sides, but the shape of the article need not be regular.

(d) Blank design

During the solid phase slip-forming process the material in the blank flows in the solid state, thus material which gathers at corners can be spread outwards to prevent folding and wrinkling. To facilitate this process, the blanks should be cut with material-deficient corners to accommodate the flowing polymer. Ideal blank design produces a forming needing little or no trimming.

(e) Mould temperature

The male mould "freezes" the forming but need not necessarily be cold. Sufficient dimensional stability may be achieved with mould temperatures up to 100°C. Adjustment of the male mould temperature causes a significant amount of thermal expansion and this may be utilised in controlling the ring/mould gap.

(f) Clamping pressure

The pressure exerted on the blank controls the force required to commence slipping. Excessive pressure leads to forces above the tensile yield of the material and hence necking. Inadequate pressure produces slipping without forming. A pressure of 20 kg/cm^2 may suitably be used.

Lubricants applied direct to the surfaces of the rings and sheet or as migratory additives in the polymer granules are considered to be a means of modifying the clamp/slip balance.

(g) Forming speeds

The downward speed of the rings plays a significant part in determining the cycle time of the process. Speeds up to 1.8 m/min are tolerable but higher rates under certain conditions produce excessive spring-back.

(h) Dwell time

The dwell time after the forming operation reduces spring back and dome panelling. If dome design and dwell are found insufficient to overcome these problems, the dwell time may be replaced by a further processing stage.

It may be desirable for certain purposes e.g. motor car components, to combine slip-forming with another forming operation to permit the production of articles of a shape which cannot be made by slip-forming alone e.g. forming articles with local depressions such as interior car door panels with cavities for arm rest and door handle. The additional forming step can, in principle, be in any possible forming operation by mechanical, hydraulic or pneumatic means, but of particular interest are other cold forming operations, such as forging, rubberpad forming and diaphragm forming.

The process will be further illustrated in the Examples which follow:

EXAMPLE 1

Sold phase slip forming condition used for production of a polypropylene suitcase shell.

Sheet thickness	1.7 mm
Male mould	550 mm × 400 mm
Depth of draw	75 mm
Sheet temperature	155°C
Clamping ring temperature	155°C
Clamping ring pressure	20 Kg/cm²
Male mould temperature	80°C
Press speed	1.8 m/min

The polypropylene shell formed under these conditions was found to have uniform thickness and suffered no spring-back.

EXAMPLE 2

A polypropylene suitcase shell 590 mm long × 440 mm wide was formed using as the feedstock a polypropylene homopolymer (Carlona (regd. Trade Mark) 'P' KM61) in the form of an embossed blue sheet 1.5 mm thick. Blanks were cut 750 mm × 600 mm.

Machinery details

1. Mould	Dimensions	587 mm × 437 mm
	Material	Cast Aluminium
	Temp	80°C
2. Clamping rings:	Ext. Dimensions	800 mm × 650 mm
	Int. Dimensions	590 mm × 440 mm
	Thickness	50 mm
	Temperature	155°C

Procedure

The blank was heated in a soak oven to 155C°, then located centrally in clamping rings and clamped at 20 kg/cm².

Forming was carried out at 800 *mm/min.*

To Load 5 seconds

To Clamp 2 seconds

To Form 10 seconds

To Eject & return 12 seconds.

The polypropylene shell produced showed good dimensional stability and a uniform thickness (±0.07 mm). Emboss retention was superior to fibreboard. The load bearing properties of the formed polypropylene shells was superior to fibreboard and recovery after deformation also better. The expected improvements in friction, abrasion and water-proofing were attained, and impact resistance to a pointed striker was higher.

EXAMPLE 3

The procedure was as described in Example 2 with the following exceptions:

Feedstock Polyethylene Carlona (regd. Trade Mark) EB196

Machinery mould temp 60°C

Clamping rings temperature 115°C

Procedure Blank heated to 115°C.

The polyethylene shell was similar to the polypropylene counterpart with the expected modifications in physical properties—higher flexibility, higher impact resistance and lower crush resistance.

EXAMPLE 4

The procedure was as described in Example 2 with the following exceptions:

Feedstock Propylene copolymer Carlona (regd. Trade Mark) 'P' MT61

Machinery Clamp rings @ 148°C

Procedure Blank heated to 148°C.

The shells produced are very suitable for the luggage application. Whilst exhibiting the advantages over fibreboard listed in Example 2, the improved impact performance of this feedstock gives a tougher moulding at the expense of marginal rigidity reductions.

EXAMPLE 5

Solid phase slip-forming condition used for production of a polypropylene shell.

Sheet thickness	1.7 mm
Male mould	550 mm × 400 mm
Depth of draw	75 mm
Sheet temperature	155°C
Clamping ring temperature	155°C
Clamping ring pressure	20 kg/cm²
Male mould temperature	80°C
Press speed	0.8 m/min

The polypropylene shell formed under these conditions was found to have uniform thickness and suffered no spring-back.

EXAMPLE 6

Solid phase slip forming conditions used for the production of an ABS luggage shell and an automotive facia panel under-tray.

Sheet thickness	1.6 mm
Male mould	550×400 mm (or 320 mm 230 mm for under-tray)
Depth of draw	110 mm (or 60 mm)
Sheet temperature	80°C
Clamping ring temperature	80°C
Clamping ring pressure	18 kg/cm²
Male mould temperature	40°C
Press speed	1.0 m/min

WHAT WE CLAIM IS:—

1. A process for making a moulded hollow article which comprises heating a sheet of a thermoplastics polymer to a temperature of between X°C and (X−35)°C where X is the crystalline melting point of crystalline polymers, or the "Vicat" softening point of amorphous polymers, clamping the sheet at its periphery by means of heated clamping rings and pressure slip-forming the sheet around a mould so that the thickness of the moulded article is substantially the same as that of the polymer sheet.

2. A process as claimed in claim 1 in which the polymer is an olefin polymer.

3. A process as claimed in claim 2 in which the olefin polymer is polyethylene.

4. A process as claimed in claim 2 in which the olefin polymer is polypropylene.

5. A process as claimed in claim 1 in which the polymer is polyvinylchloride.

6. A process as claimed in claim 1 in which the polymer is an acrylonitrile-butadiene-styrene resin.

7. A process as claimed in any one of the preceding claims in which the polymer sheet is laminated.

8. Thermoplastic moulded hollow article as claimed in any one of the preceeding claims in which a surface of the polymer sheet is modified with film, cloth or flock.

9. A process as claimed in any one of the preceeding claims in which the pressure slip forming is combined with another forming operation.

10. A process as claimed in claim 9 in which the other forming operation is solid phase pressure forming.

11. A process as claimed in claim 9 in which the other forming operation is a cold forming operation.

12. A process as claimed in any one of the preceding claims in which a clamping pressure of 14 to 24 Kg/cm² is used.

13. A process as claimed in any one of the preceding claims in which a closing rate for the clamping rings is up to 1.8 m per minute.

14. A process as claimed in any one of the preceding claims in which temperature of the mould is 20—100°C.

15. A process as claimed in claim 14 in which the temperature of the mould is 70 to 90°.

16. A process as claimed in claim 15 in which the temperature of the mould is 30 to 60°C.

17. A process as claimed in claim 4 in which the temperature of the polypropylene sheet is 135 to 170°C.

18. A process as claimed in claim 17 in which the temperature of the polypropylene sheet is 153 to 157°C.

19. A process as claimed in claim 6 in which the temperature of the ABS sheet is 55 to 90°C.

20. A process as claimed in any one of the preceding claims in which the depth of draw is 50 to 150 mm.

21. A process as claimed in any one of the preceding claims in which the thickness of the polymer sheet is up to 2 mm.

22. A process as claimed in any one of the preceding claims in which the clamping ring temperature is the same as the temperature of the polymer sheet.

23. A process as claimed in any one of the preceding claims in which the article is a luggage container.

24. A process as claimed in any one of the claims 1 to 22 in which the article is a transport vehicle component.

25. A process as claimed in claim 1 substantially as described with reference to, and as illustrated in the accompanying drawings.

26. A process for making moulded hollow articles as described in any one of the Examples.

27. Moulded hollow articles made by a process as claimed in any one of claims 1 to 26.

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2 SHEETS *This drawing is a reproduction of the Original on a reduced scale*

Sheet 1

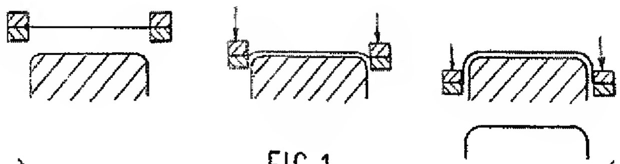

FIG.1

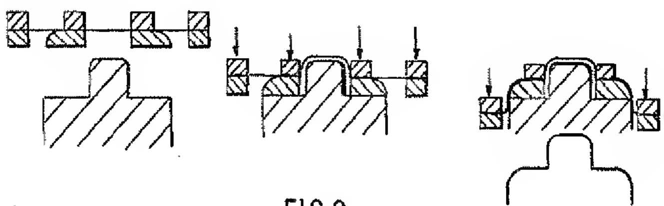

FIG.2

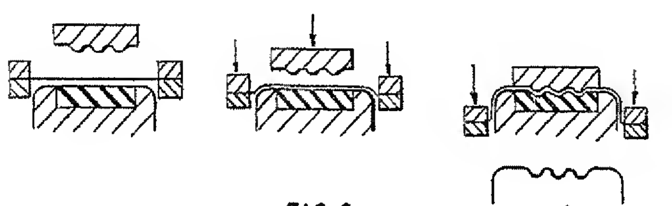

FIG.3

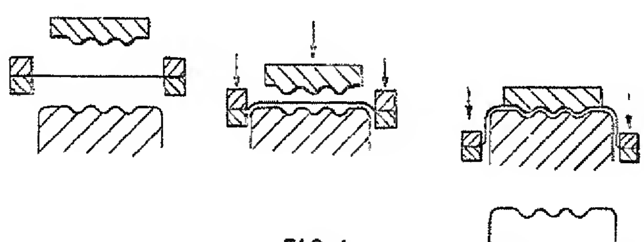

FIG.4

1386953 COMPLETE SPECIFICATION

2 SHEETS *This drawing is a reproduction of the Original on a reduced scale*

Sheet 2

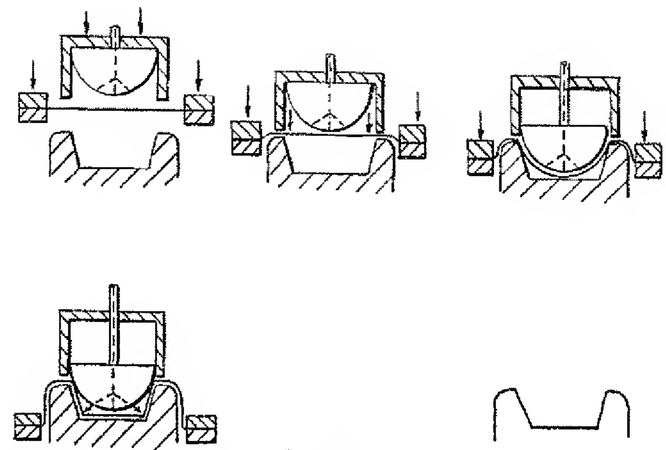

FIG.5 (1)

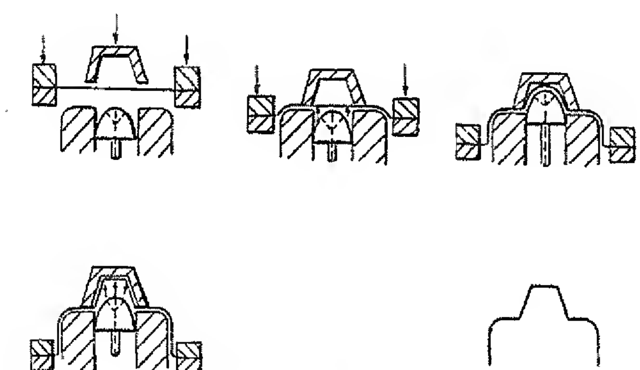

FIG.5 (2)